The paucity of data on dispersal and recolonisation arises because these processes are difficult to study using standard field techniques such as colour banding of birds or **radio-tracking** (Oakleaf *et al.*, 1993; Baptista and Gaunt, 1997). Data from genetic markers combined with knowledge of movement patterns should improve our understanding of dispersal and recolonisation (e.g. Peakall *et al.*, 2003; see Chapter 13).

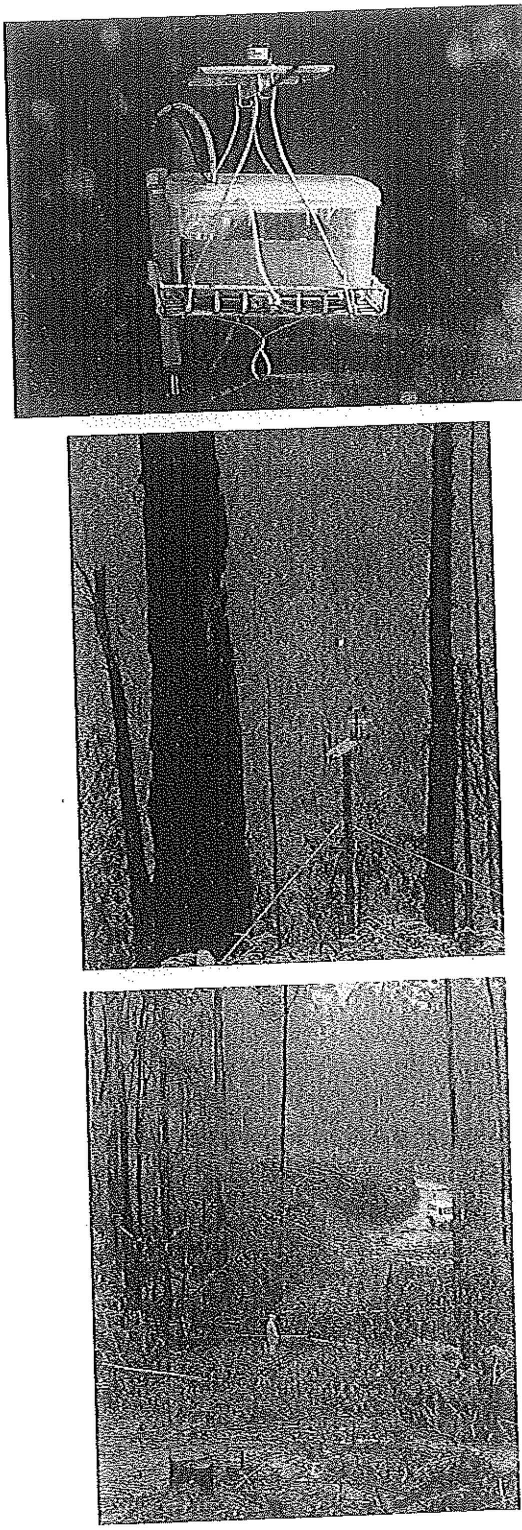
Edge effects

An edge can be viewed as a marginal zone of altered microclimatic and ecological conditions that contrasts with the interior of a patch (Matlack, 1993). Edge effects refer to the changes in biological and physical conditions that occur at an ecosystem boundary and within adjacent ecosystems (Wilcove, 1985; Temple and Cary, 1988; Kremsater and Bunnell, 1999). The term 'edge effect' is also used to describe increases in species diversity in places where two habitats meet. The ecological edge that results from a disturbance is the result of interactions between the type and intensity of the disturbance event and the ecological dynamics within the adjacent undisturbed environment. The affected measure can be an environmental variable (e.g. air temperature), an ecological process (e.g. rate of organic matter decomposition) or a community interaction (e.g. predation).

The intensity of edge effects and the area of a patch subject to significant edge influence depend on the parameter of interest. Each type of affected measure has a unique response pattern (see Figure 10.15). Two broad types of edge effects are recognised: biotic edge effects and abiotic edge effects.

Abiotic edge effects

Edges can experience microclimatic changes such as increased temperature and light and decreased humidity that extend tens or hundreds of metres from an edge, depending upon the environmental variable, the physical nature of the edge, and weather conditions (Chen *et al.*, 1990, 1991; see the review by Saunders *et al.*, 1991). These changes affect fire ignition probabilities (e.g. Kauffman and Uhl, 1990), precipitation, frost and fire behaviour (e.g. Roberts, 1973), insect activity (e.g. Simandl, 1992), nutrients (e.g. Yanai, 1991), and the composition of soil-borne bacterial and fungal populations (e.g. Jha *et al.*, 1992; reviewed by Bradshaw, 1992). In some cases, edge effects can lead to the degradation of



(Top) Equipment for measuring abiotic edge effects in Victorian Mountain Ash forests (photos by Brooke Parry). (Bottom) Accelerated tree fall at edges of clear-felled areas in Victorian Mountain Ash forests (photo by David Lindenmayer).

habitat in protected areas such as wildlife corridors (Lindenmayer *et al.*, 1997), and disrupt connectivity between larger reserved areas (Lovejoy *et al.*, 1986).

Biotic edge effects

Biological parameters that affect ecological communities across a boundary, such as diseases, weeds and predators, can penetrate hundreds of metres into retained areas (e.g. Wilcove *et al.*, 1986; Andren and Angelstam, 1988; Laurance, 1997b). Edge environments can affect reproduction, growth, and mortality in plants (Hobbs and Yates, 2003). Chen *et al.* (1991) observed increased reproduction and growth of surviving mature trees in old growth forests bordering recently clear-felled areas. Differences in invertebrate community composition have been observed between edge and interior environments (e.g. Bellinger *et al.*, 1989; Hill, 1995). For instance, amphipods responded negatively to changes in wind, moisture and temperature at the edges of forest fragments in south-eastern New South Wales (Margules *et al.*, 1994a).

In the Northern Hemisphere, some game species have strong preferences for edge environments where foraging and cover are close together (Patton, 1974; Matlack and Litvaitus, 1999). Large populations of White-tailed Deer graze food plants heavily at forest edges (Johnson *et al.*, 1995), including endangered taxa (Miller *et al.*, 1992), which can limit stand regeneration (Tilghman, 1989) and alter patterns of species diversity (McShea and Rappole, 2000).

Box 10.6

Abiotic edge effects in wet eucalypt forests

Parry (1997) measured environmental parameters at different distances from edges between clear-felled areas and adjacent unlogged stands in the Mountain Ash forests of Victoria. There were strong gradients in air temperature, vapour pressure and radiation regimes from logged/unlogged harvested area (or coupe) boundaries into unlogged forest (Parry, 1997). The measures depended on time of day, aspect, cloud cover, and forest type.

Davies *et al.* (2001b) reported that solar radiation was highest at the edges of fragments in the Wog Wog Fragmentation Experiment (see Box 10.9). Such changes may influence some elements of the invertebrate biota, for example amphipods (Margules *et al.*, 1994a).

Box 10.7

Biotic edge effects in the South Australian Mallee region

Luck *et al.* (1999a,b) studied two types of edges in the Murray Mallee region of south-east South Australia: (1) induced or abrupt human-created edges between eucalypt vegetation and human infrastructure, and (2) inherent natural edges that were gradual transitions between eucalypt vegetation and adjacent shrubland. Luck *et al.* (1999a) found that open country birds, for example the Australian Magpie and Little Raven, were often found at human-created edges but were rare in patch interiors and at natural edges. Other species, for example the Spotted Pardalote and Southern Scrub-robin, avoided human-created edges. Predation rates on artificial nests were higher at human-created edges than in interior areas, whereas there were no important edge–interior differences for natural edges (Luck *et al.*, 1999b).

These results make it possible to infer which species of birds will be susceptible to alterations of landscapes that fragment the remaining Murray Mallee habitats in ways that increase the amount of human-created edge.

Some vertebrates avoid edges (e.g. Fletcher, 2005) and are classified as 'interior' species (Gates and Gysel, 1978; Robinson *et al.*, 1995); many bird species in tropical forests fall into this category (Terborgh, 1989; Frumhoff, 1995), in part because arthropod densities are lower at the edges (Burke and Nol, 1998) or because foraging efficiency is impaired by edge conditions (McCollin, 1998).

Elevated nest predation is commonly but not universally associated with edges (Berg *et al.*, 1992; Hanski *et al.*, 1996; reviewed by Lahti, 2001). Elevated nest predation is often observed in agricultural landscapes where there are strong contrasts between vegetation remnants and the surrounding environment (e.g. Andrén, 1992; Bayne and Hobson, 1997, 1998; Hannon and Cotterill, 1998). Conversely, nest predation is less pronounced at edges in landscapes where contrasts are weaker (Schmiegelow *et al.*, 1997), such as continuous eucalypt forest dissected by minor bush tracks, or native forest abutting softwood plantations (Sargent *et al.*, 1998; Lindenmayer *et al.*, 1999g; Piper *et al.*, 2002).

Biotic responses to edges are inconsistent. Forest edges on the boundary of clear-cut areas in Sweden have lower bird species diversity (Hansson, 1983), but no such pattern occurs in clear-cut forest edges in north-eastern USA (Rudnicky and Hunter, 1993). Similarly, patterns of brood parasitism that are characteristic of edge environments in many Northern Hemisphere landscapes appear to be rare in Australia. Even within North America, the increased nest predation and brood parasitism that is observed on the eastern side of the continent is less common in the west (Kremsater and Bunnell, 1999; Marzluff and Restani, 1999).

Factors influencing edge effects
As noted for birds, the magnitude of many types of edge effects is related to the strength of the contrast between the matrix and other landscape units: where the contrast is strong, there will often be more intense interactions and edge effects (Laurance and Yensen, 1991; Mesquita *et al.*, 1999). The extent of the area supporting high contrast conditions influences the magnitude of edge effects. For example, microclimate edge effects in forests may be greater where a large clear-felled area abuts a retained patch than where a logged area or coupe is small (Lindenmayer *et al.*, 1997). Buffers can play an important role in mitigating edge effects.

Artificial nest and quail egg used in a nest predation experiment at Tumut in southern New South Wales. (Photo by Matthew Pope.)

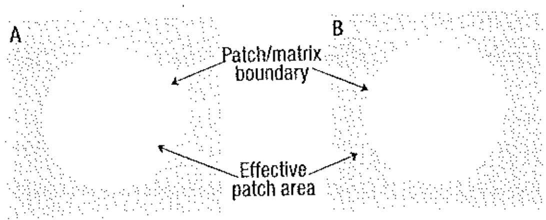


Figure 10.16. Negative and positive edge effects. (A) Processes from the matrix reduce functional patch size for the species of interest. (B) Suitable conditions in the matrix enable the species to expand its functional patch size.

'Reverse' edge effects
Edge effects are not unidirectional processes: fragments exert edge influences on adjacent matrix areas (Figure 10.16), and retained trees affect light and other abiotic factors in clear-cut areas. Birds are more likely to occur in stands of Radiata Pine in south-eastern Australia when the stands are adjacent to patches of native eucalypt forest (Tubelius *et al.*, 2004). Pest species move from remnant native forest patches into adjacent planted stands and browse and defoliate trees (Bulinski, 1999; McArthur, 2000).

Summary: edge effects
For many species, edge effects amplify the harmful impacts of fragmentation (see, for example, Lovejoy *et al.*, 1986). Changes in the environmental conditions at the edge of a patch (e.g. temperature, humidity, wind and light, and disturbances such as fire, grazing and weed invasion) decrease the effective size of a patch for those species that inhabit the original habitat. Some species favour edge habitat; regenerating vegetation and patch edges experience a seed rain of environmental weeds and other introduced plants that are frequently better adapted to exposed and disturbed environments than native plants (Janzen, 1983).

10.4 Studying habitat loss and fragmentation

Despite the importance of studying the response of species to habitat loss and fragmentation, investigations are difficult for several reasons. Some of these include:

- The way that species perceive and respond to a landscape may be very different from the way humans perceive that same landscape (see Section 10.3). For example, edge effects might mean that a 60-hectare area of native forest